Water Resources Research Institute Annual Technical Report FY 2003

Introduction

The Puerto Rico Water Resources and Environmental Research Institute (PRWRERI) is one of 54 water research centers established throughout the United States and its territories by Act of Congress in 1964 and presently operating under Section 104 of the Water Research and Development Act of 1984 (P.L. 98-242).

The general objectives of the Puerto Rico Water Resources and Environmental Research Institute are (1) to conduct research aimed at resolving local and national water resources problems, (2) to train scientists and engineers through hands-on participation in research, and (3) to facilitate the incorporation of research results in the knowledge base of water resources professionals in Puerto Rico, the U.S., the Caribbean, and Latin America as a whole.

To accomplish these objectives, the Institute identifies Puerto Rico's most important water resources research needs, funds the most relevant and meritorious research projects proposed by faculty from island universities, encourages and supports the participation of students in funded projects, and disseminates research results to scientists, engineers, and the general public.

Since its creation, the Puerto Rico Water Resources and Environmental Research Institute has sponsored a substantial number of research projects, supported jointly by federal and University of Puerto Rico's funds. The PRWRERI uses its website to make the Institute's work more widely known to, not only the Puerto Rican community, but to the whole world, and, at the same time, to provide means of information transfer with regard to the reports produced through the institute's research activities.

The PRWRERI is a component of the University of Puerto Rico at Mayaguez's Research and Development Center. As such, it acts as official liaison of the University of Puerto Rico with industry and government for all water resources research activities. The Institute also functions as a highly recognized advisor to these two sectors on water resources issues. This role translates into multidisciplinary functions and activities that add relevance and impact to the research program the Institute supports.

By virtue of the local relevance of its research and the prestige and leadership of the investigators it has supported, the Institute has become the focal point for water-related research in Puerto Rico. Meetings, seminars, technical reports, and a quarterly newsletter are used by the Institute to keep the water resources community and general public informed about advances in research. Approximately once every two years, the Institute organizes major conferences on water-related research in Puerto Rico and the Caribbean, in collaboration with other technical organizations in the region. All these activities facilitate the translation of the research sponsored by the Institute into practical applications of direct benefit to industry, government, and the general public.

In addition to the 104 program, the PRWRERI conduct research in water resources and environment-related areas funded by a diversity of federal and state government agencies and industries. These non-104 program research activities comprise over 75% of the research funds at the Institute. Some of the most relevant research projects during FY2003 are as follows.

GROUNDWATER WELLS AND WATER SPRING INVENTORY FOR PUERTO RICO (sponsored by Puerto Rico Aqueducts and Sewer Authority)

The Puerto Rico Aqueducts and Sewage Authority (PRASA), in cooperation with the Puerto Rico Electric Power Authority (PREPA) and other government agencies are partnering with the Department of Natural and Environmental Resources (DNER) to bring up to date the Integral Plan for Conservation, Development, and Use of Water Resources of Puerto Rico, shortly called the Water Use Plan.

One essential piece of information to update the Water Use Plan is to know the hydraulic capacity, physical characteristics, and exact location of the groundwater wells, as well as the water springs, in Puerto Rico. The US Geological Survey and the Commonwealth of Puerto Rico have created an inventory of groundwater wells and water springs. However, this inventory must be updated from values taken in from 1960 to 1985.

This project uses GIS technology, and detailed survey information to obtain location and physical characteristics of the most productive groundwater wells in the Island. Domestic wells from PRASA, agricultural farms, commercial, and industrial users are being visited to collect the required information. A data base is under construction, which will work on a GIS platform and will provide all information related to a particular well, including maps and photographs. The final product will be a fully updated inventory and a better estimate of the groundwater use in Puerto Rico.

AGRICULTURAL WATER USE STUDY FOR PUERTO RICO (sponsored by Puerto Rico Aqueducts and Sewer Authority)

Also part of the Water Use Plan for Puerto Rico, this study is intended to determine the agricultural water demand for the whole Island. Using GIS techniques, actual water use for different crops, CAFOS, and other agricultural activities was determined. The results are presented tabulated and graphically using electronically generated maps. Water demand projections were calculated for 2025. This was accomplished by projecting the agricultural land use to 2025 and combining with the determined water use for each agricultural sector.

SPATIAL AND TEMPORAL SEDIMENT TRANSPORT PROCESSES (sponsored by the Engineering Research and Development Center of the U.S. Army Corps of Engineers)

The objectives of this research are to expand the knowledge of sediment transport processes in river systems, particularly with respect to the source and ultimate fate of sediments, and to define the scaling (time and space) relationships for transport processes as they apply to local and regional transport calculations.

The project contains a intensive field data collection part. Three watersheds from different parts of the world are being surveyed to obtain cross sectional geometry, and bed and bank sediment samples. These information will be use to estimate sediment load for testing new geomorphic models under development by the Engineering Research and Development Center of the U.S. Army Corps of Engineers.

The Añasco River in Puerto Rico, Hawkcombe Stream in England, and Abiaca River in Mississippi, US, were selected for comparison purposes. The sampling process at Puerto Rico and United States is finished and will be ongoing during July 2004 in England.

ANALYSIS OF SEDIMENT TRANSPORT PROCESSES IN SELECTED LATIN AMERICAN STREAMS (sponsored by the Engineering Research and Development Center of the U.S. Army Corps of Engineers)

This project has two components: one is associated with technology transfer and the other with sediment data collection. The objective is to expand the knowledge of sediment transport processes and measures for the effective regional management of these sediments by analyzing several channel systems in Latin America as well as, provide training to engineers and scientists in Latin America.

The project involves promoting relations within sediment transport researchers and students by providing training in river hydraulics and geomorphology. At the same time, information on sediment data from the visited countries is requested from private and government agencies. At least, four countries are being visited for these purposes. Next visit is scheduled to Costa Rica where data collection and training will be offered during June 2004. Uruguay is scheduled for September 2004.

DETAILED LANDUSE INVENTORY FOR 2003 FOR THE JOBOS BAY NATIONAL ESTUARINE RESEARCH RESERVE (sponsored by the Department of Natural and Environmental Resources and NOAA)

The Jobos Bay National Estuarine Research Reserve (JBNERR) is located between the municipalities of Salinas and Guayama on the southeast coast of Puerto Rico. Its mission is to manage, operate and protect the local estuarine habitats and resources. Jobos Bay is a natural resource that many people use for economical purposes as well as recreational activities. The goal of the reserve is to promote a balanced level between human activities and the protection of the estuarine habitats and resources.

The JBNERR has 2,800 acres of tidal and submerged wetlands; important wildlife habitats are part of the reserve limits. Endangered species live within the reserve. Since the bay is an estuary, its preservation is of extreme importance because it is home to various species that need it to spawn or spend part of their life cycle. To these animals, any impediment, like contaminants, can imply an alteration in their life cycle, hampering the reproduction of future generations.

During the last 20 years, the Jobos Bay National Estuarine Research Reserve (JBNERR) watershed area has gone through rapid changes in landuse. Changes in the landuse, irrigation methods and the increase in groundwater extraction, due to industrial and urban development, represent a serious threat to the overall water supply and water quality of the area. In collaboration with the JBNERR, the PRWRERI developed a detailed landuse of the area using remote sensing technology and field visits. This type of detailed landuse is needed to clearly evaluate changes in the watershed. This classification also assists in the development of more comprehensive conservation management plans. Next phase is to incorporate this database to modeling efforts using previously developed water quality models for the Jobos Bay watershed.

CONCEPTUAL COMPARISON AMONG AIR QUALITY PREDICTION MODELS FOR THE JOBOS BAY NATIONAL ESTUARINE RESEARCH RESERVE (sponsored by the Department of Natural and Environmental Resources and NOAA)

Recent industrial developments in the vicinity of the JBNERR could represent a potential threat to the air and water quality of the reserve. The first coal-fired electric power plant ever established in Puerto Rico started operations about a year ago in a location which is very close to the JBNERR. Other industrial sources of air pollutants in the area include the Aguirre's power generation thermal plant of the Puerto Rico Electric Power Authority (PREPA), and pharmaceutical plants. The air pollutants emitted by these sources are likely being transported to the JBNERR air basin, with a concomitant deterioration of the air quality. Some of these airborne pollutants could possibly settle down over the ground and water surfaces producing soil and aquatic pollution. For this reason, it is very important for the JBNERR management to obtain the technical tools needed to accurately assess the prevailing air quality in the region, to model the impact that the existing air pollution sources are having, and to predict in advance the probable impact of new proposed sources in the aerial basin.

The objective of the this work is to make recommendations to the management of the JBNERR regarding the selection of the most appropriate tools for air quality modeling of the local air basin. In the selection of a model to predict air quality the following activities must be included. 1. To establish the potential uses that the management of the JBNERR will have for the results obtained from the air quality modeling activities. 2. To locate sources of baseline data on present air quality in the region. 3. To characterize the major sources of air pollutants in the region. 4. To locate sources of meteorological and topographical data in the area. 5. To screen the available air quality models by selecting those models that meet the necessary requirements defined in activity 1 and using the data identified in activities 2, 3, and 4. 6. To make recommendations to the management of the JBNERR regarding the selection of the most appropriate tools for air quality modeling of the local air basin.

DETERMINATION OF NUMERIC NUTRIENT TARGET CRITERIA IN SURFACE WATERS OF PUERTO RICO (sponsored by the PR Environmental Quality Board)

The rapid degradation of the quality of surface waters is a matter of increasing concern. Despite the success of a number of initiatives undertaken by the Clean Water Act the task of cleaning the nation waters is far from being achieved. According to recent estimates close to 40% of the waters being monitored at the national level do not meet quality standards to support designated uses. A similar situation is observed in Puerto Rico. The 2002 water quality inventory of Puerto Rico reports that 67% of the river miles being monitored were impaired. In most cases the cause of impairment has been attributed to excessive sediment and bacteria levels. Interestingly, nutrients have yet to be identified as a major cause of impairment in Puerto Rico. This contrasts with estimates by the National Water Quality Inventory, which lists nutrients as the leading cause of water pollution in the U.S. More than 3.4 million acres of lakes and reservoirs and 84,000 miles of rivers and streams are believed to be impaired as a result of excess nutrients at the national level. The fact that nutrients are not regarded as a major pollution cause in Puerto Rico may be due to the lack of an adequate standard that allows for the identification of nutrient impaired waters. The current water quality standard for phosphorus in Puerto Rico, 1000 µg Total P L-1, corresponds to the maximum discharge load allowed to point sources by USEPA. Numeric phosphorus criteria adopted in other regions of the U.S. place this value between 8 - 40 µg P L-1 for lakes (a 30- 50% increase may be expected for rivers). Based exclusively on chemical analyses results of lakes our research group calculated a value of 19.5 µg P L-1 as a numeric standard for phosphorus in Puerto Rico. However, this value should be refined from empirical studies that consider the relationship between aquatic biomass growth, nutrient ratios, and nutrient loads in tropical surface waters.

Although phospohorus is usually the limiting factor for aquatic biomass growth in surface waters, nitrogen is also relevant, particularly in coastal waters. Usually a 10:1 N/P ratio is used as criteria to define which nutrient limits aquatic biomass growth. In Puerto Rico, a 10mg L-1 TKN is used as a drinking water criteria. However, numeric criteria aimed at preserving the natural status and protecting the biological and chemical integrity of surface waters has yet to be established. Numeric criteria proposed for other ecoregions of the U.S. range between 0.1 1.68 mg/L TN for lakes, and between 0.12 to 2.18 mg/L for rivers. This study is intended to develop numeric criteria for nutrients (nitrogen and phosphorus) in Puerto Rico. The project consists of several phases in which numeric targets will be determined for lakes, followed by rivers with a potential extension phase to cover coastal waters.

THE RIO GRANDE DE ARECIBO WATERSHED: CHARACTERIZATION AND MANAGEMENT OF NON-POINT POLLUTION SOURCES (sponsored by the Department of Natural and Environmental Resources and the PR Environmental Quality Board)

Biological growth in surface waters due to nutrient over-enrichment is a major source of water pollution in the United States. Sediments and bacteria are considered the main surface water quality impairments in Puerto Rico, because nutrient (especially total phosphorus (P)) concentrations do not usually exceed the current water quality standard for total P of 1000 μg/L. It has recently been suggested that the current water quality standard for P greatly underestimates the effects of nutrients on aquatic biomass growth and that appropriate nutrient criteria for P should be significantly lower than the current value. Immediate evaluation of the nutrient dynamics in stream waters, assessment of sources, and linkage between sources and water-quality targets must be performed in order to improve or at least maintain Puerto Ricos surface water quality. In this project we are performing quantitative evaluation of nutrient, bacterial and sediment dynamics in stream waters draining from small sub-watersheds with well-defined land use within the Rio Grande de Arecibo (RGA) Watershed. Water samples are being collected at regular bi-weekly intervals and during storm events using automated water samplers. Sediment, nutrient and bacterial concentrations are related to discharge using synoptic or continuous stream-flow measurements. Refinement of the current land-use classification will permit direct linkages between non-point sources located within the sub-watersheds and discharges, which will enable us to develop export coefficients for conditions in Puerto Rico. Management alternatives will be suggested that will enable remedial activities that will eventually result in improvement of water-quality to the RGA watershed.

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Puerto Rico. Management alternatives will be suggested that will enable remedial activities that will eventually result in improvement of water-quality to the RGA watershed.

Research Program

During FY 2003, the PRWRERI did not engaged in research projects funded by 104 program. Funds assigned to the Institute through the 104 program were used for administration and one information transfer related project. Funds used in administration have resulted in additional funds attracted by the Institute from other agencies as discussed in the introduction section of this report.

The administration phase of the Institute takes approximately half the amount of funds assigned to the institute. The other half is used for research funding and is offered to the scientific community through our call for proposal. Proposals are encouraged at about $20,000 funding level. This seems to lack attractiveness since no research proposals were received. Only one education related project proposal was received and was funded with $43,000. This is presented in the next section.

Well and Interstitial Water Crop Protection Chemicals Study on the Salinas Fan

Basic Information

Title:	Well and Interstitial Water Crop Protection Chemicals Study on the Salinas Fan
Project Number:	2002PR5B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	N/A
Research Category:	None
Focus Category:	Water Quality, Solute Transport, Toxic Substances
Descriptors:	None
Principal Investigators:	jose.dumas.1

Publication

Final Report

Start: 04/01/2002
End: 06/26/2004

Title: Well and Interstitial Water Crop Protection Chemicals in the Salinas Fan Delta Aquifer

Investigators : José A. Dumas-Rodríguez and Rafael Montalvo-Zapata, Crop Protection Department, Agricultural Sciences College, University of Puerto Rico Mayaguez Campus.

Focus Categories: TS, WQL, WL

Congressional District: (N/A)

Statements of the critical water problems:
This project examines the groundwater and interstitial water quality, toxic substances and non point contamination in the Jobos Basin Estuarine Reserve. Jobos Bay is located between the Salinas and Guayama municipalities on the south coast of Puerto Rico and comprises more than 2,800 acres, including a forest and a mangrove. The Jobos Estuaries Ecosystem has been severely stressed since the late 80s by land and water channel alterations which have changed the water flow patterns of the zone. One key issue that needs to be addressed in Puerto Rico and worldwide is the pesticide and phthalate ester movement in soil and groundwater, and their effects on sensitive environmental zones, including flora, fish and wildlife.

Non-managed application of pesticides and other compounds that reach non target sites may result in leaving residues where crops will later be planted or where these residues may reach surface and ground water resources. No intensive research in Puerto Rico related to organic pollution in the Jobos mangrove zone has been carried out. The proposed field and laboratory research will be the first to help provide a more comprehensive view of water quality in the zone. Besides it will be complementary t o another research project currently under way related to nitrate levels in the zone.

Statements of the results or benefits:
The expected benefits of the proposed research will be the development and advancement of new scientific information related to pesticide and organic toxic residues in the groundwater and interstitial water in the Salinas and Guayama municipalities. Agriculture is expected to continue in the zone, and water sampling for the presence of crop protection chemicals is necessary to ensure human health and the protection and conservation of the environment. The project will also provide risk/benefit data for decisions concerning chemical usage. Data for the year 2002-2003 will be analyzed, interpreted, results, findings and conclusions will be submitted as either technical papers on referred journals, oral presentations and posters during the following year. There will be one or two publications associated with the completion of the research.

Methodology:

Sample collection, preservation and handling

Pollutant analysis will be conducted at the Agricultural Experiment Station Pesticide Laboratory. Water samples were collected from fifteen wells from agricultural growing areas of the Jobos basin zone, and from twenty-five piezometers on the Jobos Reserve (Table 1 and 2). Piezometers were at the north, west and east zones of Jobos Basin, parallel to the abandoned stream channel and in the Esmeralda fault, north of the bedrock hill at the Aguirre sugar mill. The selected sampling wells and piezometers were sited by GPS. Water samples were taken monthly for one year. Triplicate samples were collected in one-liter dark-brown glass bottles with Teflon lined caps (pre-washed with detergent and hot tap water, rinsed with distilled and de-ionized water, and dried in an oven at 400 C for 1 h). All water samples were placed in an ice chest at around 4 C and transferred to the Central Analytical and Pesticide Laboratories at Rio Piedras on the same collecting day. Sodium thiosulphate and copper metal (80 mg/L) were added as needed to remove residual chlorine and sulfur, respectively. The samples were stored at 4 C in a refrigerator from the time of collection until extraction, which was done the next day after collection. All water samples were filtered through a Whatman GB/F filter, followed by a Nylon membrane filter before chemical analysis.

Table 1. Wells identification, location and geographic position

			Geographic Position					
Well No	**Well id**	**Sector**	**North**			**West**		
W1	Aguirre 2	Aguirre	17°	58'	049"	66°	13'	524"
W2	Aguirre 3	Aguirre	17°	57'	901"	66°	15'	121"
W3	Esperanza	Esperanza	17°	57'	632"	66°	15'	271"
W4	Salich	Salich	17°	57'	638"	66°	16'	115"
W5	Vasquez	Las Mareas	ND					
W6	Soler1	Fortuna	17°	58'	127"	66°	15'	150"
W7	Jaguas 1	Jaguas	17°	58'	696"	66°	15'	690"
W8	Jaguas 2	Jaguas	17°	58'	737"	66°	15'	872"
W9	Vega	Fortuna	17°	58'	264"	66°	15'	437"
W10	Gonzalez	Fortuna	17°	59'	363"	66°	16'	275"
W11	Gonzalez Grua	Fortuna	17°	58'	801"	66°	15'	262"
W12	Gonzalez Antena	Fortuna	17°	58'	683"	66°	14'	961"
W13	Lanausse 1	Aguirre	17°	58'	747"	66°	14'	752"
W14	Lanausse 2	Aguirre	17°	59'	160"	66°	14'	757"
W15*	Gonzalez Antena 2	Fortuna	17°	58'	801"	66°	15'	262"

* well very close to W12

ND-No was determined

Analysis of pesticides and other types of organic compounds:

Organic compounds were extracted following the US EPA method 8270, which includes 259 semi-volatile organic compounds and/or SPE-disk method outlined by Muller. A 1-L water sample, was filtered through a glass fiber filter, and extracted. Analyses were performed by GC/MS using a DB-5 capillary column and an appropriate computer system.

Table 2. Piezometer identification, location and geographic position

Piezometer id	Sector	Location	Geographic Position North			West		
P1S1	S1	Aguirre Forest	17°	57'	442"	66°	13'	141"
P2S1	S1	Aguirre Forest	17°	57'	432"	66°	13'	151"
P3S1	S1	Aguirre Forest	17°	57'	421"	66°	13'	149"
P4S1	S1	Aguirre Forest	17°	57'	478"	66°	13'	159"
P5S1	S1	Aguirre South	17°	57	490	66°	13	183"
P6S1	S1	Aguirre South	17°	57	515	66°	13	198"
P7S1	S1	Aguirre South	17°	57	519	66°	13	216"
P1S2	S2	Aguirre South	17°	57'	110"	66°	14'	853"
P2S2	S2	Aguirre South	17°	57'	0"	66°	14'	841"
P3S2	S2	Aguirre South	17°	57'	19"	66°	14'	870"
P4S2	S2	Aguirre South	17°	57'	001"	66°	14'	865"
P5S2	S2	Aguirre South	17°	56'	984"	66°	14'	846"
P1S3	S3	Las Mareas	17°	57'	64"	66°	15'	710"
P2S3	S3	Las Mareas	17°	57'	29"	66°	15'	672"
P3S3	S3	Las Mareas	17°	57'	15"	66°	15'	673"
P4S3	S3	Las Mareas	17°	57'	068"	66°	15'	735"
P5S3	S3	Las Mareas	17°	57'	001"	66°	15'	665"
P1S4	S4	Aguirre	17°	57'	207"	66°	14'	846"
P2S4	S4	Aguirre	17°	57'	215"	66°	14'	847"
P3S4	S4	Aguirre	17°	57'	221"	66°	14'	846"
P4S4	S4	Aguirre	17°	57'	188"	66°	14'	851"
P5S4	S4	Aguirre	17°	57'	173"	66°	14'	854"
P6S4	S4	Aguirre	17°	57'	164"	66°	14'	846"
P7S4	S4	Aguirre	17°	57'	181"	66°	14'	839"
P8S4	S4	Aguirre	17°	57'	186"	66°	14'	853"

Ammonium, nitrate, nitrite, pH, conductivity and phosphate

These chemical analyses were conducted at the Central Analytical Laboratory. Ammonium, nitrate and nitrite were analyzed by using the EPA method 353.2. Phosphate was analyzed by the EPA method 365.1. The water samples were preserved at 4 C with diluted sulfuric acid to pH <2 until the analysis.

Soil microbial biomass C and N

Soil core samples were collected from the selected sampling sites for interstitial water monitoring (S1, S2, S3 and S4). The selected areas were in the north, west and east Jobos basin zones; near the Rio Nigua, parallel to the abandoned stream channel, and in the Esmeralda fault, north of the bedrock hill at Aguirre Sugar Mill. Soil samples were placed in plastic bags, transferred to Rio Piedras, and then dried at 40 C. The 100 g of soil were rewetted to 15% moisture to stimulate microbial activity, and then incubated at 25 C for 5 days. Soil microbial biomass C was determined by fumigation incubation by exposing 40 -g soil samples rewetted and incubated for 5 d to alcohol free $CHCl_3$ vapor for 24 h. The vapors were evacuated and removed. The soil samples were incubated in a 1-L gas-tight glass container for 10 days at 25 C. The evolved carbon dioxide was trapped in 1N KOH and determined by titration with 1N HCL. The quantity of CO2-C was divided by an efficiency factor of 0.41 to calculate microbial biomass C (Anderson, 1982; Haney, 2000).

Soil microbial biomass N was determined by analyzing NH4-N concentration of fumigated samples following 10-d incubation period minus initial NH4-N prior fumigation, divided by an efficiency factor of 0.41. The NH4-N was extracted from 7 -g soil sample using 28 ml of 2M KCl. Samples were shaken for 30 min in a reciprocal shaker and filtered, and the extracts were analyzed for NH4-N by using an autoanalyzer.

Determination of clay and organic carbon content

Clay, sand, silt, plus inorganic and organic carbon contents were determined by using standard methods reported elsewhere (Blake, 1965). Sampling plots were all areas from which the soil samples for microbial analyses were collected.

Adsorption Desorption studies

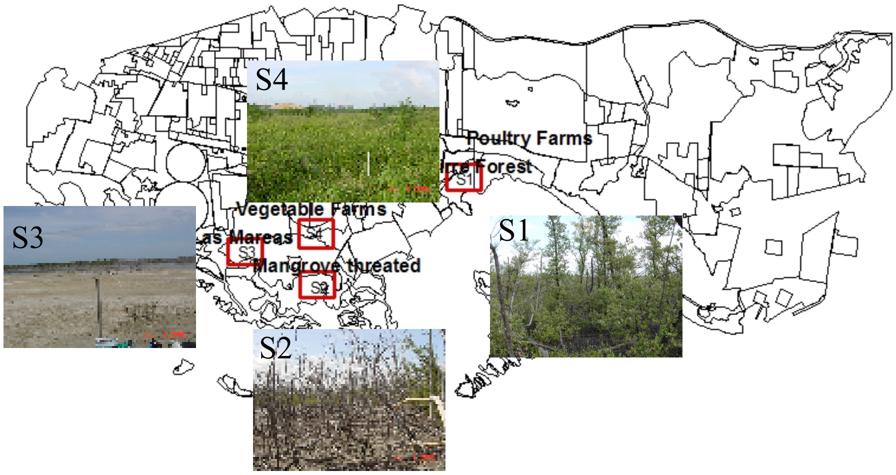
Adsorption were expressed as k-Freundlich values. A stock solution of 40 ppm in distilled and de-ionized water will be prepared for ametryne by using Mangle Muerto and Sorgo soil collected in the selected plot area mentioned. Concentrations o f 0.5, 1,5,10,20,40 ppm will be prepared by dilution with 0.01N $CaCl_2$ solution prepared with distilled and de-ionized water. Batch equilibrium sorption and desorption isotherms were obtained for ametryne in both soils (Liu, 1997). The laboratory tests were conducted by treating 1 g of air dried soil with 10 ml of the selected compound solution in a sealed test tube. The suspensions were protected from light with aluminum paper, kept at 22 C, and placed in a shaker for 24 h. Then, they were centrifuged for 10 min at 2500 rpm and a 5 -ml aliquot of t he clear supernatant solution was analyzed by the used of a HPLC system coupled to a UV/vis detector. The adsorption curves for pesticides and k- values were determined by use Freundlich model.

Point of zero salt effect (pzse)

Potentiometric titration method at selected ionic strengths was used for measuring pzse from soil collected in the sampling zone. The batch method outlined elsewhere was used to calculated pzse (Sparks, 1982).

Principal Findings and Significance:

Human activities in the municipalities of Salinas-Guayama adjacent to a threatened natural reserve, have increased concern regarding environment. Agriculture, dumping, Junker businesses, excessive ground water demand are polluting the Jobos Estuaries Reserve. A study was conducted in this zone to determine pollutants in ground and interstitial waters. Four sampling zones were selected for interstitial water monitoring. The central and west zones (S2, S3 and S4) are intensely cultivated with banana, plantain, papaya, sorghum, sunflower, soybean and other agricultural commodities upstream. The south central zone (S2) is severely affected by mangrove death, and the southern area is on a salt flat zone (S3) (Figure 1). The northern central selected area (S4) was intensely cultivated in sorghum.



EXPLANATION
- S1,S2,S3,and S4 -Sampling sectors where piezometers were sunk

Figure 1. Jobos Bay interstitial water-collection sites in the study area in Salinas Puerto Rico

During the April 2002 to February 2003 period, water samples were collected to determine pH, conductivity, NO_3, NO_2, NH_4, TOC, TC, IC, Zn, Fe, Pb, Cu, toxic organic compounds and pesticides. The water samples showed a high content of organic compounds, and many of them were long chain hydrocarbons and alcohols as identified by GC-MS.

Some interstitial water samples in the central zone of JBNERR resulted in positive detection of the organochloride insecticides lindane (BHC) and pentachlorophenol (PCP). These insecticides and wood preservative, respectively, were extensively used in the sugarcane plantations and wood treatment about 40 years ago. Herbicides such as atrazine, ametryne and monuron, the fungicide o-phenylphenol and the plant regulator diphenylamine (coraza) were detected in the interstitial water (table 3). Atrazine was found in piezometers at S4 sampling area. Atrazine was found at levels close to 0.5 ug/L probably because of piezometer proximity to an abandoned sorghum growing area. The other pesticides detected were not quantified. Pesticide traces were found in three of the four monitoring zones selected for this study (S2-Aguirre South, S3-Las Mareas and S4-Aguirre North). Other harmful compounds were detected in these zones, such as N-methyformamide, 1,2-benzene dicarboxilic acid, diethyl ester and benzene alcohol (Table 3). All sampling zones had few mangroves growing or had mangrove death problems, except Aguirre Forest (S1). Therefore decreased degradation rates of toxic compounds in the environment may be taking place in S2, S3 and S4 areas.

Table 3. Summary of results of wells and piezometers sampled for recognized and suspected human hazard contaminants

Chemical	CASRN	use or type	frequency (%)	
			well[a]	piezometer[b]
1-Tetradecanol (ALFOL 14)	112-72-1	hair tonics	16	9
Acetophenone	98-86-2	fragrance	1	19
(Capric acid) Decanoic acid	334-48-5	pesticide	3	3
(Coraza, Shield) Benzeneamine, N-phenyl	122-39-4	pesticide	3	8
Caffeine	58-08-2	stimulant	0	11
(Muscalure) 9-tricosene, (Z)-	27519-02-4	pesticide	1	1
methanone. diphenyl	119-61-9	comestic	3	0
camphor	76-22-2	analgesic	1	0
(E)-tricos-9-ene	35857-62-6	pesticide	0	1
phenanthrene	85-01-8	PAH	0	1
Phosphoric acid, tributyl ester	126-73-8	herbicide	1	6
1,2-benzenwdicarboxylic acid, butyl phenol	85-68-7	plasticizer	5	7
1,2-Benzenedicarboxilic acid, diethyl ester	84-66-2	plasticizer	2	1
Bisphenol A	80-05-7	plastic and printing	0	5
nonylphenol	25154-52-3	detergent	6	8
phenol,2-(1,1-dimethylethyl)-4methyl)	2409-55-4	---	1	0
Phenol,4-chloro-3-methyl	59-50-7	pesticide	0	1
Di(2-ethylhexyl)adipate	103-23-1	plasticizer	0	1
(P-Cresol) Phenol,4-methyl	106-44-5	Paint	1	0
(-lindane) D-BHC	319-84-6	pesticide	0	2
Ametryne	834-12-8	herbicide	0	1
Benzaldehyde, 4-hydroxy-3-methoxy	121-33-5	---	1	1
1,2-Benzenediol, 4-(1,1-dimethylethyl)	98-29-3	printing	1	4
1,3-Isobenzofurandione	85-44-9	rubber and paint	0	1
O-Phenylphenol	90-43-7	Bactericides	0	2
Benzophenone	119-61-9	hair product, ink	0	1
Anthraquinone	84-65-1	---	0	1
Monuron	150-68-5	herbicide	0	1

Chemical	CASRN	use or type	frequency (%)	
			well[a]	piezometer[b]
Methanone (2-hydroxy-4-ethoxyphenyl)phenone	131-57-7	paint and plastic	0	1
Benzeneamine, N- nitroso-N-phenyl	86-30-6	rubber	2	0
formamide	123-39-7	---	3	4
octyl phenol isomer	1806-26-4	---	2	2
Atrazine	1912-24-9	herbicide	1	2
Amphetamine	300-62-9	stimulant	0	2
PCP	87-86-5	pesticide	0	2

[a]well samples No. - 77
[b]piezometer samples No. - 172

Nitrate levels between 0.11 and 5.00 g/mL were found only in one piezometer, the closest to a sorghum growing area in the Aguirre north zone (S4). Phosphorus levels between 0.5 and 30 g/m, which is over the environmental background level of 0.03 g/ml, were found only in Aguirre Forest interstitial water (S1). . The high levels found for nitrate and phosphate pinpoint hot point sources near S1 and S4 sampling areas. Lead, cooper and zinc were detected in some interstitial waters. Lead levels were between 0.11 and 1.69, over environmental background of 0.015 g/ml; copper levels were between 0.03 and 0.58 g/ml; and zinc levels were between 0.05 and 0.37 g/ml.

Table 4. Summary of average of the average values found for inorganic contaminants in interstitial water

statistical	Pb (g/ml)	NH4 (g/ml)	NO3 (g/ml)	Cu (g/ml)	Zn (g/ml)	Fe (g/ml)	PO4 (g/ml)
mean	0.78	1.43	0.72	0.15	0.07	0.58	3.85
std dev.	0.49	1.47	1.09	0.17	0.06	0.52	6.61
maximum ave. value	1.69	4.95	3.75	0.58	0.20	1.74	20.00

Higher interstitial water pH was found in the S4 sampling area ranging between 8.0 and 8.4, where the remaining sampling zones had values ranging between 7.3 and 8.0. Strong differences in the amount of dissolved oxygen (DO) in the interstitial water were observed among the four selected sampling zones. No detectable DO levels were found in sampling site S1. However, sampling sites S2 and S3 had levels between 23 and 66, and 10 and 39 mg/L, respectively. Higher DO levels were observed in sampling site S4 with levels between 70 and 82 mg/L. The low DO levels in the S1 sampling area are in accord with higher levels of dissolved organic matter expected in this zone (a mangrove forest), because the organic matter decreases levels of available oxygen in water. The highest interstitial water conductivity was found in S2-Mangle Muerto area (165 mS/cm), with an average value higher than that of the salt flat area of S3-Las Mareas (124 mS/cm). Bosque Aguirre (S1) and Sorgo (S4) had average interstitial water conductivity of 94 and 2.7 mS/cm, respectively.

Regarding groundwater analysis, the major contaminant in the monitoring wells, all of them on agricultural land, was nitrate, with a high variability with time due rainfall, irrigation rate and fertilizer application. Phosphate was not detected in the sampled wells, thus suggesting that its presence in piezometers from Aguirre Forest comes from non agricultural sources. Lead, cooper and zinc were not detected in the sampled wells. Atrazine, a s-triazine herbicide was detected (below 0.1 g/L) in some monitoring wells, and traces of pesticides such as diphenyl amine (Coraza) and 4-chloro-3methyl phenol (4-chlor-m-cresol) were detected (Table 3).

Soil was analyzed to determine nutrient levels, other types of inorganic pollutants and the point of zero salt effect (pzse) at each of the selected interstitial water sampling places (Table 5 and 6). Higher lead concentration was detected in soil in S3 (Las Mareas) than in the other sampling zones. This is a potential threat to human health because this is a highly populated area and must be carefully monitored. A very low organic matter content was found in S2 (mangrove threat area) compared to that of S1 (Aguirre Forest). This fact joined with lower values of potassium, calcium, magnesium and a higher pH value than in the S1 area is indirect data to suggest shifting of microbial fauna and flora that is taking place in the S2 area.

Table 5. Soil analysis in places where interstitial waters were monitored.

Sampling Place1/	P (ug kg^{-1})	Ca (%)2/	K (%)2/	Mg (ug/g)2/	Pb (ug/g)3/	Cd (ug/g)3/	Cu (ug/g)2/	NH4 (ug/g)4/	NO3 (ug/g)4/
S1	139 (±77)	0.63 (±0.11)	0.21 (±0.06)	0.57 (±0.20)	1.5	nd	0.61	14 (±4)	nd
S2	42 (±14)	0.53 (±0.05)	0.20 (±0.02)	0.53 (±0.07)	nd	nd	___	20 (±4)	nd
S3	44 (±16)	0.50 (±0.11)	0.13 (±0.03)	0.27 (±0.08)	160	nd	0.12	17 (±7)	12 (±17)
S4	24 (±4)	0.62 (±0.03)	0.04 (±0.01)	0.14 (±0.03)	0.87	nd	0.17	20 (±9)	12 (±6)

1/Samples collected from at least three areas for each sampling place. Each area was replicated six time; 2/exchangeable cation (NH4OAc pH 7); 3/total; 4/exchangeable KCl 2N.

Table 6. Particle size analysis of soils in places where interstitial waters were monitored .

Sampling Place1/	pH	M.O.(%)	N (%)2/	Cu (ug/g)2/	Zn (ug/g)2/	Fe (%)2/	Silt (%)	Lime (%)	Clay (%)
S1	7.7 (±0.3)	10.7 (±4.0)	0.25 (±0.11)	70 (±2)	102 (±51)	1.8	30 (±19)	57 (±13)	13 (±6)
S2	8.0(±0.2)	14.0(±8.50)	0.31 (±0.11)	44(±4)	53 (±9)	0.8	22 (±9)	58 (±7)	20 (±6)
S3	8.3 (±0.1)	2.3 (±1.3)	0.13 (±0.07)	73 (±8)	121 (±38)	0.1	24 (±14)	63 (±24)	13 (±10)
S4	8.4 (±0.5)	3.3 (±0.6)	0.18 (±0.03)	76(±3)	88 (±2)	1.6	36 (±8)	23 (±11)	41 (±8)

1/amples collected from at least three areas for each sampling place. Each area was replicated six time; 2/total

The point of zero salt effect was determined from soil samples taken in the four sampling zones (S1, S2 S3 and S4) by the potentiometric titration method. Sodium chloride as indifferent salt was used to bring all samples to an equal state of saturation in order to compare different soils. The point of zero salt effect was determined from the crossover point of net electric charge vs. pH curves of the soil at three ionic strengths (Fig. 2). To calculate net electric charge the following equation was used:

$$H- \quad OH = [10^{-pH_B}-10^{-pH_s}]-[10^{-(14-pH_B)}-10^{-(14-pH_s)}]x100/(W\ x \quad)$$

where
 H- OH = proton surface charge density
pH_B = pH of the blank solution
pH_s = pH of the solution equilibrated with the sample
 = single ion activity coefficient calculated with the Davies equation
W = soil sample weight (g)

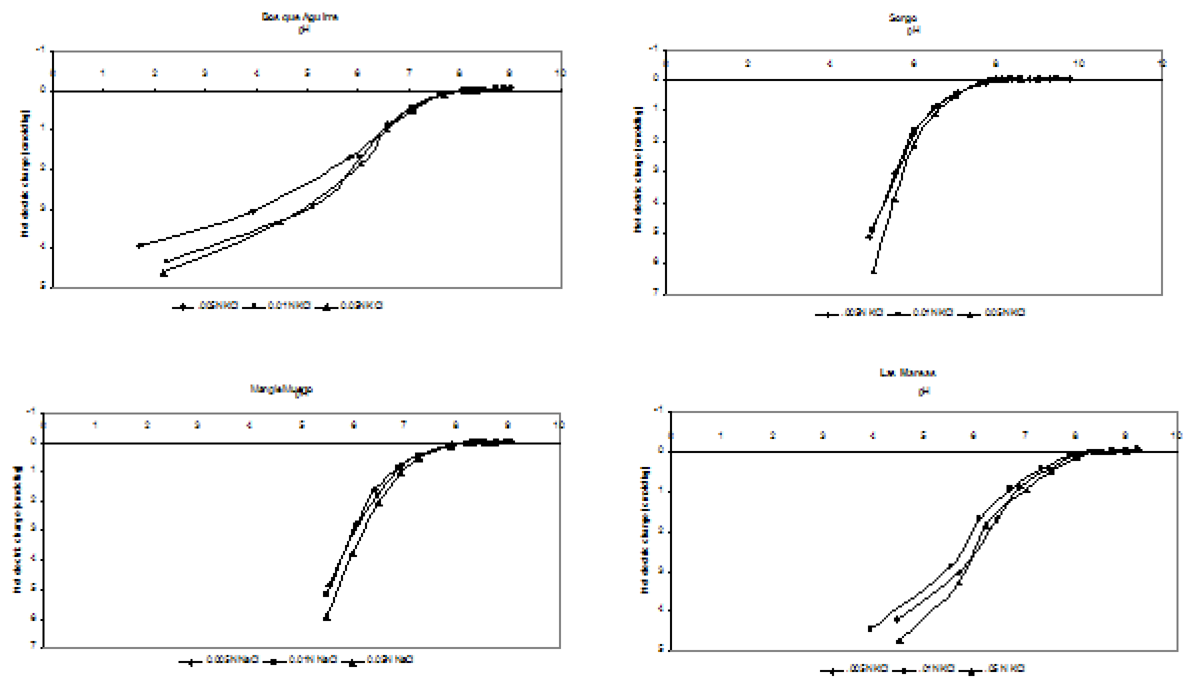


Figure 2. The net electric charge of Bosque Aguirre, Sorgo, Mangle Muerto and Las Mareas soils as determined by potentiometric titration.

Similar points of zero salt effect (pzse) for sampled soils, Bosque Aguirre (8.0), Mangle Muerto (8.1), and Las Mareas (8.3) soils were observed, except Sorgo soil which had the lowest pzse of 7.0. However, Bosque Aguirre had the lowest proton surface charge density changes with pH and Mangle Muerto the highest one. This is an important factor to be considered to figure out potential environmental effects of ionizable compounds, such as ametryne, a s-triazine basic herbicide frequently used for crop protection in this zone.

Ametryne was chosen as a model molecule to study the adsorption isotherm of an ionizable compound in Mangle Muerto and Sorgo soils. A simple Freundlich isotherm fits the empirical values obtained for both soil (Fig.3).

Freundlich isotherm equation is

$$\log C_s = \log K_d + 1/n \log C_e$$

Both isotherms had a c-type behavior which is in accord with a 1/n value of 1 where the Freundlich expresion becomes simply a distribution coefficient given by

$$C_s = K_d C_e$$

K_d value is an important parameter governing mobility of the compound in the soil, where high K_d value indicates a low mobility.

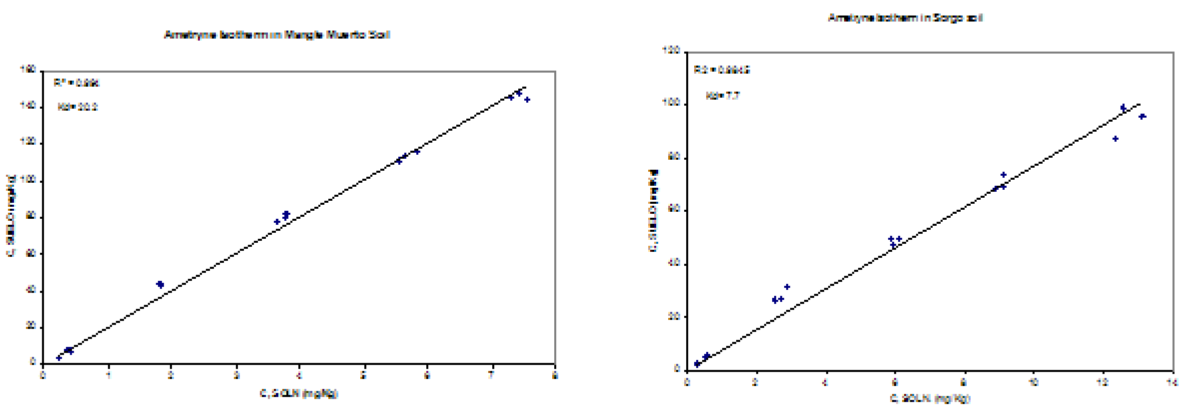


Figure 3. Freundlich adsorption isotherm for ametryne in Mangle Muerto and Sorgo Soils

A higher K_d value was obtained for Mangle Muerto Soil (20.2) than Sorgo soil (7.7), all of which suggests a higher capacity of Mangle Muerto soil to adsorb and remove this compound from running and interstitial water. This finding is in accord with the proton adsorption graph mentioned above and shows the remarkable capacity of estuarine soil to retain toxic ionizable compounds (Fig. 2). The adsorption- desorption process is an important process that must be studied because it plays an important role in toxic compound environmental impact. The desorption experiment carried out for ametryne by the serial method in Mangle Muerto and Sorgo soil, to determine whether ametryne is reversibly ot irreversibly adsorbed in these soils, showed a linear Freundlich desorption isotherm (Fig. 4). This type of pattern allows the use of a simplified Freundlich desorption equation

$$C_s = K_{des} C_e$$

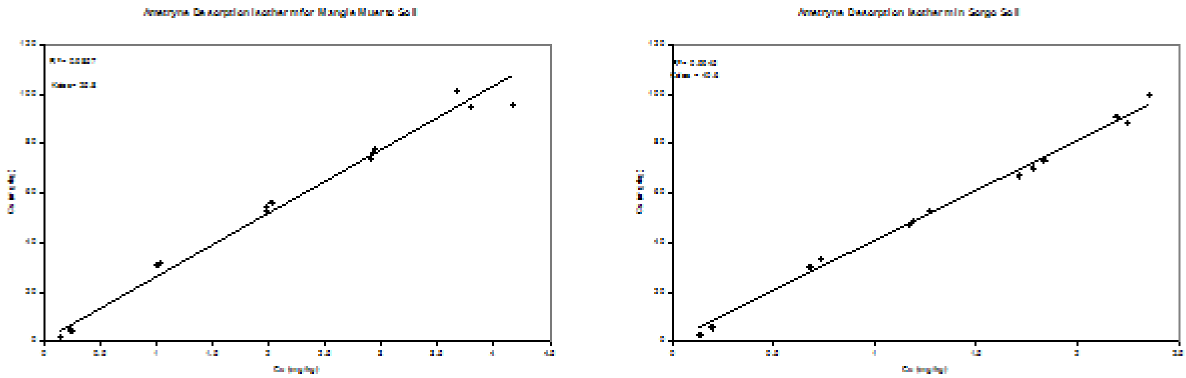


Figure 4. Freundlich desorption isotherm for ametryne in Mangle Muerto and Sorgo Soils (48 h).

These experiments showed a high Kdes value for Mangle Muerto (25.8) and Sorgo (40.6) soils suggesting a low desorption kinetic of this herbicide in both soils, especially in Sorgo soil.

Laboratory tests were done to measure C and N microbial biomass in the four sampling zones. Aguirre Forest, an area not affected by death of mangroves, had higher C microbial biomass than the other sampling areas in Jobos Bay. This finding is in accord with healthy mangrove growing. However, N soil microbial biomass was lower in Aguirre Forest than in the S2 area, a mangrove death zone. This finding suggests a potential ecosystem health threat (Table 5). A second confirmation trial showed higher levels of C microbial biomass, and had an N microbial biomass profile different from that of the first. The first trial had C microbial biomass between 120 and 190 cg kg^{-1}.The N microbial biomass for the first trial was between non detectable and 25 mg kg^{-1}. The second trial had C and N microbial biomass between 330 and 370 cg Kg^{-1} and between 5 and 24 mg kg^{-1}, respectively. Spatial variability and changes in climatological condition during the second soil sample collection for the trial may have been responsible for the differences between the first preliminary sampling and the second (Table 7). The low range of N microbial biomass, especially in the S2 and S3 zones, is not a characteristic sign of a healthy soil and requires a more extensive study.

Table 7. Microbial biomass-C and N in the four selected sampling sites

Place	Second samples set	
	Average (cgCO2/Kg)	Average (mgNH4/kg)
S1	349 (±8)	14 (±13)
S2	370 (±40)	5 (±5)
S3	360 (±32)	8 (±4)
S4	330 (±13)	24 (±21)

ND-non detectable; s- standard deviation

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Anderson, J.P.E. 1982. Soil respiration. Pages 837-871 in A.L. Page et. al., eds, Methods of Soil Analysis. Madison, WI: American Society of Agronomy and Soil Science Society of America.

Haney, R.L. S.A. Senseman, F.M. Hons, and D.A. Zuberer. 2000. Effect of glyphosate on soil microbial activity and biomass. Weed Science 48:89-93.

Blake, G.R. Particle Density and Bulk density Pages 371-390 in C.A. Black et al, eds Methods of Soil Analysis. Madison, WI: American Society of Agronomy and Soil Science Society of America.

Sparks, D. L., Ed. *Methods of Soil Analysis. Part 3- Chemical Methods*; Soil Science Society of America and American Society of Agronomy: Wisconsin, 1996.

Related Presentations and publications:

Dumas, J.A., R. Montalvo, and O. Rosario. 2004. Ground Water Quality Under Pineapple Growing Fields in Manati Quadrangle of Puerto Rico: A Tropical Karst Zone,.Panorama Ambiental (in press)

Dumas, J.A., R. Montalvo, and O. Rosario. 2003. Ground water Quality under pineapple growing fields in Manati Quadrangle of Puerto Rico, A tropical Karst Zoned; Well and interstitial water crop chemicals study on the Salinas Fan. Oral presentation. Asociacion Interamericana de Ingenieria Sanitaria y del Ambiente (AIDIS). Tropimar Convention Center. April 4.

Senseman, S. A., T. C. Mueller, T. C., R. D. Wauchope, C. Clegg, R. W. Young, L.M.Southwick, M. B. Riley, H. A. Moye, J. A. Dumas, W. Mersie, J. D. Mattice, and R. B. Leidy. 2003. Interlaboratory Comparison of Extraction Efficiency of Pesticides from Surface and Laboratory Water Using Solid Phase Extraction Disks. Journal of Agricultural and Food Chemistry 51:3748-3752.

Dumas, J.A., R.Montalvo, P. Casanova, E. Rivera, N. Corchado, and Z. Nieto. 2002. Well and interstitial water study in the Salinas Fan. Memorias Reunion Cientifica Anual Sopca 2002 (poster)

Dumas J.A., R. Montalvo. 2003. Well and Interstitial Water Crop Protection Chemicals in the Salina Fan Delta Aquifer. Simposio de Investigacion Y Restauracion Estuarina. 2-3 octubre. Wyndhan El San Juan Hotel y Casino. Isla Verde.

Mersie W., C. Clegg, D. Wauchope, J.A. Dumas, R.B. Leidy, M.B. Riley, E.W. Young, J. Mattice, T.C. Mueller, S.A Senseman. 2002. Interlaboratory Comparison of Pesticide Recovery From Water Using Solid-Phase Extraction Disks. Journal of A.O.A.C. 85(6):1324-1330.

Information Transfer Program

The only one 104-program project initiated during FY 2003 was an information transfer related project. Actually, this project develops a course for the graduate program of the Environmental Engineering area of the Department of Civil Engineering at the University of Puerto Rico at Mayaguez. Funds were used solely for the purchase of equipment needed for the field measurement course. The project had some administrative drawbacks, which precluded the completion as originally proposed. The director of the Institute has authorized a non-fund time extension of one year. This time extension should allow the PIs to finish the drilling and installation of the pumping and observation wells.

FIELD METHODS IN HYDROLOGY AND HYDRAULIC

Basic Information

Title:	FIELD METHODS IN HYDROLOGY AND HYDRAULIC
Project Number:	2003PR13B
Start Date:	3/1/2003
End Date:	2/1/2005
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	Education, Hydrology, Methods
Descriptors:	
Principal Investigators:	Ingrid Yamill Padilla, Raul Zapata

Publication

SYNOPSIS

Project Number: 2003PR13B Start: 3/1/2003
End: 2/1/2004

Title: Field Methods in Hydrology and Hydraulic

Investigators: Padilla, Ingrid Y., Zapata, Raul

Focus Categories: Education, Hydrology, Methods

Congressional District:

Descriptors: Field Methods, Hydrologic Measurements

Problem and Research Objectives:

The Department of Civil Engineering and Surveying at the University of Puerto Rico, Mayagüez begun a Doctoral program in Environmental and Water Resources Engineering during the year 2002. This program generated the need for a new and innovative curriculum of graduate courses to train scientist in these vital areas. It is also necessary to provide the students with practical field experience, which will bilaterally strengthen the theoretical and analytical skills developed during the forming years.

The Water Resources and Environmental Research Institute is taking an active role in promoting higher level education and helping to fill the gab between theoretical and applied engineering science. One major obstacle to fulfill this task is the lack of appropriate equipment for field measurements. By supplying instrumentation for the creation of the “Hydrologic and Hydraulic Field Measurement” course, this proposal is a step forward and a major contribution to improve the formation of new scientists in the water resources and environmental areas.

This project requested the instrumentation necessary to create an applied measurements course titled “Hydrologic and Hydraulic Field Measurement”. The course objective is to provide graduate students from the MS and PhD program in Water Resources and Environmental Engineering with field experience in measurement of hydrologic and hydraulic parameters, as well as field reconnaissance work for research and applied engineering applications.

Methodology:

The course was initially created at the departmental and institutional level to be offered as an official graduate course. It was created as a graduate course that can be taken by entry-level M.S., as well as senior Ph.D. students having fundamental knowledge in hydraulics and hydrology. The course creation had involved four faculty members from surface water and groundwater hydrology and hydraulics.

Seven field/experimental activities were initially planned and scheduled as shown in the attached syllabus and briefly summarized in Table 1. Each of the field activities were preceded by a lecture explaining the methods to be used. The field/experimental activities were followed by periods of data evaluation, analysis, and documentation. All students were required to prepare written reports student for each of the activities.

Table 1. Field/experimental activities included in the course "*Field Methods in Hydrology and Hydraulic*".

Activity	Topic	Description
1	Climatic Variable Analysis	Students install a portable weather station, collect climatic data from this and other USGS' and NWS' weather stations around the island, and perform various data analyses. Climatic variables measured include rainfall, temperature, wind speed and direction, solar radiation, humidity, and vapor pressure. Lectures include techniques for collecting and presenting the data, operation principles of the instrumentation, and procedures for the analyses. The analyses include, but are not limited to, statistical analyses, completeness and consistency tests, and frequency analysis.
2	Evaporation and Evapotranspiration	Students take daily measurements from and maintain a Class A Evaporation Pan during the entire semester. The data collected is used to calibrate various evaporation models. The students model evaporation in different sites and assess the results. The models take into energy balance, aerodynamics, and combined evaporation principles. Evapotranspiration is assessed by means of a lysimeter built by the students. The data is used to calibrate some models and to develop relationships between evaporation, and actual and potential evapotranspiration. The data is also applied to determine the monthly pan evaporation coefficient.
3	Infiltration	Students install field infiltrometers and perform infiltration tests in the on different types of soils. The data collected is used to assess the infiltration characteristic of the soils tested and to calibrate different empirical models. Parameter estimation of most commonly used models are emphasized.
4	Surface Water Hydraulic Measurement	Students are trained in the use of a variety of field equipments to measure fundamental hydraulic and geometric parameters, which are required for river or channel studies. The classroom lecture includes presentation and demonstration of the different field tests and their importance in river hydraulics. Several selected stream reaches are selected and surveyed by the students. Cross section elevation and station points are surveyed and located using GPS equipment for accurate location. Students learn to tale stage and stream discharge measurements using a stage markers, topographic surveys, and flow propeller. A depth sounder is used to obtain channel elevation below the water surface. The range finder and the inclinometer allow a quick estimation of the river width and the banks height.
5	Sediment Transport	Students are initially offered a review lecture on fundamentals of sediment transport, where the equipment and sampling procedures are presented and demonstrated. The lecture is followed by field reconnaissance of at least two sediment sampling sites. The sampling equipment is set at the selected sites and field measurements of discharge and suspended and bed sediments are taken to obtain sediment loads. Bed, bank and flood plain materials are collected from representative sites for sediment size distribution analysis in the laboratory. The students select, from previous class discussion, several sediment transport functions and apply them to the field data. Results are compared with measured values for selection of the more appropriate equations and sediment loads are modeled.

Table 1. Field/experimental activities included in the course "*Field Methods in Hydrology and Hydraulic*" – Continued.

6	Pumping and Specific Capacity Test	This activity requires the installation of a pumping well. The well is to be installed at the UPRM campus for instructional purposes. The specific capacity test involves pumping a production well at a given (design) flow rate while monitoring water levels, drawdowns, and flow rates at the well. Once water levels have reached "steady state" at the well for a given flow rate, the pumping rate is instantaneously changed to a higher flow rate while continuously monitoring water levels, drawdown, and flow rates. This procedure is repeated at least four times to establish the relationship between well yield and drawdown. Regression analysis and groundwater analytical models are then used to analyze the data and determine well yield capacity.
7	Aquifer Test and Groundwater Sampling	This activity requires the installation of a pumping well and an observation well. The aquifers test involves pumping a production well at a constant rate for 2 days, while monitoring water levels and drawdowns at the pumping well and the nearby observation well. Flow rates at the pumping rate are also monitored throughout the test. Once the data is collected, it is analyzed using groundwater flow analytical models. Groundwater is collected at the discharge point from the production well and sampled from the observation well using a bailer. The samples are analyzed for temperature, pH, conductance, and TDS. The data is used to model aquifer properties and production capacity.

Principal Findings and Significance:

The course was created as a Civil Enginnering course (INCI 6116) and offered during the fall semester of the 2003-2004 academic year. Although a civil engineering course, it is open to graduate students from other areas, as long as they possess fundamental knowledge on hydrology and hydraulics concepts. Five graduate civil engineering students registered: 3 were at the M.S. level and 2 were at the Ph.D. level.

The course scheduled followed the attached *Course Syllabus* (Apendix 1). All field activities were conducted successfully as planned and described in Table 1, except for the last 2 activities related to groundwater hydrology ad hydraulics. The groundwater field activities were delayed because, although all the documentation was submitted months prior to the commencement of the academic semester, the permit for well drilling and installation was not obtained on time. This permit must be given by the Puerto Rico Department of Natural and Environmental Resources prior to any well drilling and installation activity.

Most of the field activities were successfully implemented and carried out. Students leaned about the instrumentation and methods of hydrologic and hydraulic field activities and applied theoretical concepts on the analysis of the measured parameters. Some problems were encountered in the installation and data analysis of the lysimeters and infiltrometers, but those problems have been solved for the next time the course is offered.

Although the issues related to the well installation permit have been resolved at this time, they were not resolved prior to the end of the academic semester when the course (INCI 6116) was offered. At the end of the semester it was then decided to extend the course to the following semester to allow time for permit approval and give the students the opportunity to conduct the proposed, groundwater-related activities. Unfortunately, the permits and contract were not issued on time and the proposed groundwater field activities were not completed. The students were taken to nearby observation wells were use groundwater and GPS instrumentation to measure water levels, well location, and elevation. The data obtained was used to determine groundwater potentiometric elevation and flow directions. Because this activity lack a significant component of the proposed groundwater work, the field procedures and methods were thoroughly explained and data from other specific capacity and aquifer tests were then provided to the students for analysis. Evaluation of the groundwater field work was based on the field work conducted in the nearby observation wells and on the data analysis of the specific capacity and aquifer tests. All well installation permits have been and the institution is making all the pertinent arrangements for well installation in September, 2004. All students will be invited to see the well installation equipment and methods.

The learning objectives for the course were evaluated from written reports submitted by the students. The final grades were based on 6 individual written report grades. The general objectives of the course were accomplished in this project. Students learned the practical and theoretical principles of hydrologic and hydraulic measurements in the field. This course has further exposed them to the instrumentation and difficulties and errors involved in field measurements and data interpretation. It has given them the basis to understand and visualize the data they often encounter for analysis and decision making.

TRAINING ACCOMPLISMENTS

List all students participating in Section 104 projects.

Field of study	Academic Level				Total
	Undergraduate	MS	Ph.D.	Post Ph.D.	
Chemistry					
Engineering:					
Agricultural					
Civil		3	2		5
Chemical					
Computer					
Electrical					
Industrial					
Mechanical					
Geology					
Hydrology					
Agronomy					
Biology					
Ecology					
Fisheries, Wildlife, and Forestry					
Computer Science					
Economics					
Geography					
Law					
Resources Planning					
Social Sciences					
Business Administration					
Other (specify)					
Totals					

APPENDIX 1

University of Puerto Rico
Mayagüez Campus
College of Engineering

Syllabus & Instructor Information Sheet Form

A. COURSE SYLLABUS

1. General Information:

Course Number: INCI 6116
Course Title: Hydrologic and Hydraulic Field Measurement Methods
Credit-Hours: 3

2. Course Description:

This course provides graduate students at masters and doctoral levels the knowledge and skills required for using field equipment, sampling techniques, and data analysis for hydrologic and hydraulic applications. The course uses widely accepted and tested measurement techniques and equipment. The course provides students with useful measurement tools, skills for equipment use, and data analysis methodologies for climatologic, river hydraulics, and field measurements for their independent research needs. It requires extensive field work.

3. Pre-requisites: None

4. Textbook, Supplies and Other Resources:

Class Notes

5. Purpose:

The purpose of the course is to provide students with useful measurement tools, skills for equipment use, sampling techniques and data collection and analysis in hydrologic and hydraulic sciences and engineering.

6. Course Goals: By the end of this course, the students will be able to …

- Know, comprehend, apply and analyze fundamental hydrologic and hydraulic measurement techniques.
- Apply field measurement techniques to collect and analyze hydrologic and hydraulic data.
- Conduct sampling and testing of surface water, groundwater and sediments.
- Conduct field reconnaissance work for research and applied engineering applications.
- Analyze and interpret hydrologic and hydraulic field data.
- Report and present data analysis and results.

7. Requirements:

- Compulsory fieldwork attendance.
- Intensive fieldwork participation.
- The use of personal computers is required. Written reports, graphs, diagrams, and drawings are to be made through personal computers using word processors, electronic spreadsheets, and presentation graphics.
- Turn in the homework, special problems and project, and reports on time.
- Follow safety and security procedures.
- Keep all notes in an accessible field notebook.
- **E-mail:** All students must have an e-mail account to receive important course notes, updates, and changes. The e-mail address will be provided to the instructor, via e-mail. Students are responsible ton check for material sent through e-mail.

8. Laboratory/Field Work (If applicable):

No laboratory work. See attached schedule for fieldwork.

9. Department/Campus Policies:

9a. **Class attendance:** Class and fieldwork attendance is compulsory. The University of Puerto Rico, Mayagüez Campus, reserves the right to deal at any time with individual cases of non-attendance. Professors are expected to record the absences of their students. Frequent absences affect the final grade, and may even result in total loss of credits. Arranging to make up work missed because of legitimate class absence is the responsibility of the student (see Bulletin of Information Undergraduate Studies, 2002-2003).

9b. **Absence from field work:** Students are required to attend field work. If a student is absent, he or she will receive a grade of zero in the fieldwork component.

9c. **Final examinations:** Final written examinations must be given in all courses unless, in the judgment of the Dean, the nature of the subject makes it impracticable. Final examinations scheduled by arrangements must be given during the examination period prescribed in the Academic Calendar, including Saturdays. (see Bulletin of Information Undergraduate Studies, 2002-2003).

9d. **Partial withdrawals:** A student may withdraw from individual courses at any time during the term, but before the deadline established in the University Academic Calendar. (see Bulletin of Information Undergraduate Studies, 2002-2003).

9e. **Complete withdrawals:** A student may completely withdraw from the University of Puerto Rico, Mayagüez Campus, at any time up to the last day of classes. (see Bulletin of Information Undergraduate Studies, 2002-2003).

9f. **Disabilities:** All the reasonable accommodations according to the Americans with Disability Act (ADA) Law will be coordinated with the Dean of Students and in accordance with the particular needs of the student.

9g. **Ethics:** Any academic fraud is subject to the disciplinary sanctions described in article 14 and 16 of the revised General Student Bylaws of the University of Puerto Rico contained in Certification 018-1997-98 of the Board of Trustees. The professor will follow the norms established in articles 1-5 of the Bylaws.

10. General Topics:

Lecture	Topic	Reading Material
1 (8/13)	Introduction & Safety Issues	Handout, References
2 (8/19)	Climatic Variable Analysis	Handout, References
3 (8/26)	Evaporation and Evapotranspiration	Handout, References
4 (9/2)	Infiltration	Handout, References
5 (9/9)	SW Hydraulic Measurement	Handout, References
6 (9/16)	Sediment Transport	Handout, References
7 (9/30)	Pumping and Specific Capacity Test	Handout, References
8 (10/21)	Aquifer Test and Groundwater Sampling	Handout, References

FIELDWORK SCHEDULE

Laboratory	Topic	Report Due Date	Reading Material
1 (8/20, 8/27)	Climatic Variable Analysis	9/2	Handouts, References
2 (9/3)	Evaporation and Evapotranspiration	11/18	Handouts, References
3 (9/10)	Infiltration	9/16	Handouts, References
4 (9/17, 9/24)	SW Hydraulic Measurement	10/7	Handouts, References
5 (9/17, 9/24)	Sediment Transport	10/14	Handouts, References
6 (10/1)	Pumping and Specific Capacity Test	10/21	Handouts, References
7 (10/22)	Aquifer Test and Groundwater Sampling	11/4	Handouts, References

University of Puerto Rico
Mayagüez Campus
College of Engineering

B. Instructor Information Sheet

1. General Information:

Instructor: Dr. Walter Silva
Title: Professor
Office: Stefani 110A
Phone: 832-4040 ext. 3494
E-mail: wsilva@uprm.edu
Office Hours: MWF 10:30-12:30
(Other hours by Appointment)
Co-Instructors: Dr. Jorge Rivera-Santos, Raul Zapata, Dr. Ingrid Padilla
e-mail: riveraj@uprm.edu, Zapata@ce.uprm.edu, Ingrid@ce.uprm.edu

2. Course Description:

Course Number: INCI 6116
Course Title: Hydrologic and Hydraulic Field Measurement Methods
See element number 2 (Course Description) of Course Syllabus Section.

3. Purpose:

See element number 5 (Purpose) of Course Syllabus Section.

4. Course Goals:

See element number 6 (Course Goals) of Course Syllabus Section.

5. Instructional Strategy:

- Conference
- Fieldwork
- Sampling
- Testing
- Oral/written Reports

6. Evaluation/Grade Reporting:

Grades will be based on attendance, fieldwork participation, written reports, and oral presentations. Special problems and short projects may also be given at the instructor's discretion. The weighting will be as follows: Attendance and fieldwork participation (45%), written reports (45%), and oral presentation (10%).

In general, 90-100% = A, 80-89% = B, 70-79% = C, 60-69% = D, <60% = F

9. Deadlines for Assignments (Optional):
The instructor will give deadlines for each activity. All work must be turned during class, on the day is due. After that, 5 points will be taken off per day for 5 days. No assignment will be accepted after 5 days of its due date.

10. Student Assistance (If applicable):

11. Attendance and Behavior:

- Attendance to class and fieldwork is mandatory. If you miss a class, you need to present a written excuse to the professor. Missing class more than 3 times may be grounds to lower your final grade at the professor's discretion. After 3, each absence will result in 1 point off the final class grade.
- Students are required to attend all fieldwork. If you miss a (one) field activity for a justifiable reason acceptable to the professor, you need a written excuse. Otherwise, a grade of zero will be given to the missed fieldwork component. Missing more than one field activity you will be given the opportunity to withdraw from the class or you will receive an F".
- Students are encouraged to share, discuss, and interact; however, all graded work must be done independently, except as noted by instructor. Plagiarism: the penalty for academic dishonesty is failure on the piece of work.
- **Use of beepers and cellular phones is prohibited during class hours**

12. Instructor Responsibilities (If applicable):
- Help to obtain and prepare samples, plan fieldwork standard procedures, assist in fieldwork preparation, provide tutorial support to students.
- Preliminary schedule will be announced at the beginning of the semester, but the dates and times are subjected to changes. If rescheduling is necessary, the new dates and times will be announced with at least one week in advance.

13. Course Outline And Schedule:

a) **Course Outline.** See element 10 (General Topics) of course Syllabus for topics. General topics to be covered follow in approximate order. The instructor may, if necessary, change the order of the topics.

b) **Approximate Schedule.** Approximate schedule for reports and presentation follows. The instructor may, if necessary, change the scheduled dates in coordination with the students.

i. Written Report- See element 10 (General Topics) of course Syllabus.
ii. Oral Presentation – November 26, 2003; December 3, 2003.

14. Additional References:

i. Biedernharn, Elliot and Watson, *The West Stream Investigation and Streambank Stabilization Handbook*, U.S. Army Corps of Engineers, 1997.

ii. Dahmen and Hall, *Screening of Hydrologic Data*, ILRI Publication No. 49, 1990.

iii. Dawson, K.J. and Istok, J.D., *Aquifer Testing: Design and Analysis of Pumping and Slug Tests*, Lewis Publishers, 1991.

iv. Driscoll, F.G., *Groundwater and Wells*, 2nd ed., Johnson Division, 1986.

v. Ferguson, *Stormwater Infiltration*, Lewis Publishers, 1994.

vi. Fetter, C. W., *Applied Hydrogeology*, 4th ed., Prentice Hall, 2001.

vii. Goldman, Jackson, and Burszdynsky, *Erosion and Sediment Control Handbook*, McGraw Hill, 1986.

viii. Heath, R., *Basic Ground-Water Hydrology*, U.S. Geological Survey Water-Supply Paper 2220, 1989.

ix. Kasenow, M., *Applied Ground-water Hydrology and Well Hydraulics*, Water Resources Publications, LLC, 2000.

x. Lal, R., *Soil Erosion Research Methods*, Soil and Water Conservation Society, 1994.

xi. Meadows and Walski, *Computer Applications in Hydraulic Engineering*, Haestad Methods, 2002.

xii. Roberson,,J.A., J. Cassidy, and Chaudhry, *Hydraulic Engineering*, 2nd Ed., John Wiley, 1997.

xiii. U.S. Army Corps of Engineers, *Hydrographic Surveying*, EM 1110-2-1003, 1991.

xiv. Yang, C.T., *Sediment Transport Theory and Practice*, McGraw Hill, 1996.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	0	0	0	3
Masters	3	0	0	0	3
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	7	0	0	0	7

Notable Awards and Achievements

Publications from Prior Projects